WATERPROOFING OF CONCRETE BY ADDITION OF COMMERCIAL COMPOUNDS

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ARMOUR INSTITUTE OF TECHNOLOGY

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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY

IN CIVIL ENGINEERING

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Introduction

The waterproofing of concrete and cement mortars is an art which has developed in comparatively recent years. The indifferent results attendant upon the addition of soaps and alum has led to the development and placing on the market of a large number of patented and secret preparations , sold under different trade names and with rather glowing promises of the manufacturers. Many of the foremost cement men in the country at present believe that there is no truly successful method of waterproofing concrete.

The difficulty attendant upon the securing of good concrete , together with the unskilled class of labor usually employed in concrete work , demand additional qualities of the waterproofing in excess of the obvious property of efficient waterproofing value. Some of these may be enumerated as follows .

(1). The waterproofing should be effective thru out the entire mass of the concrete. If applied merely on the surface , the development of any checks or cracks ; or any injury to the concrete in the form of a scratch or abrasion affords an entrance for water which will permeate the entire mass.

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(2). It is desirable that the use of the waterproofing add no further complications to the steps in securing a good concrete. A waterproofing which is mixed on the job affords an objection in that it complicates the making of the concrete ; and , because of the small percentage used , it increases the chance of a batch of poorly waterproofed or entirely unwaterproofed concrete going into the work.

(3). The addition of the waterproofing must not injure the quality of the cement ; especially in tension , compression , soundness or time of set.

(4). The cost of waterproofing must not be so great as to outweigh the advantages to be gained.

The development of concrete waterproofing has been along three general lines : 1st, the use of outside surface coverings ; 2nd , the application of paints ; 3rd , ingredients incorporated with the concrete itself.

1st. This method consists of covering the concrete with tarred paper , felts , asphalt preparations and similar materials and has been found its most extensive use in roofing.

2nd. The application to the concrete of various preparations in the form of paints , which are supposed to provide an impervious membrane over the face of

the concrete. The liability to injury by scratching and checking is the great objection to this method. 3rd. The third method may itself be divided into two general classes. In the first of these a paste or liquid is used. This method demands mixing on the job. The paste or liquid , usually of the consistency of thick , sour cream , is shipped in barrels or cans. One part of the material must be thoroughly mixed with , usually , twelve to sixteen parts of water , and this solution used in place of clear water in mixing the concrete. The difficulty of securing thorough mixing with water of a water repelling material, the necessity of constant agitation to prevent the settling out of the compound , and the large opportunity for error through low grade labor are the chief objections to this method.

In the second division of mixtures , a powder is used. These powders do not as a rule , differ greatly in weight and appearance from the cement itself. The general method of use is to mix from two to three percent by weight of the powder with the dry cement. This cement is then used in the regular way for making the concrete. The powder may be mixed in any one of three ways : it may be mixed by hand ; it may be mixed by some type of machine ; or it may be added

in the manufacture of the cement itself.

Cement is hygroscopic , and from the time it leaves the mills it gathers moisture. The difficulty of thoroughly and uniformly mixing any quantity of a powder with fifty times its own weight of another by hand condemns hand mixing for any but very small jobs.

Running the cement and the powder through a mixing mill ; either hand or power is an improvement over hand mixing but is itself far from absolute , especially if the cement is slightly damp.

The satisfactory method of mixing the powder with the cement isin the manufacture of the cement itself. There the dryness of the cement and the very means itself insures an absolutely uniform and even distribution of the powder through the cement.

To test the values of various compounds on the market to be mixed with concrete for waterproofing the same a series of tests were made for thesis work at the Armour Institute of Technology , Chicago Illinois ; extending from March 8th to April 10th, 1911.

An eastern L high cement was used throughout. Six different brands of waterproofing were employed

and, for each test, specimens were made of the cement waterproofed by each of the brands of waterproofing, as well as one specimen made from the plain unwaterproofed cement.

Special care was taken to have all specimens made for any test , by the same operator , at the same time and under uniform conditions.

It was found that the use of different compounds made necessary different amounts of water to obtain the same consistency. Here consistencies were kept uniform rather than actual amounts of water.

The waterproofing powders were hand mixed with the dry cement. Thirty pounds of cement was waterproofed at a time ; by mixing for seven minutes with an ordinary shovel.

In the casee of both powders and pastes ; the percentages advocated by the manufacturers for conditions met in ordinary tunnel or retaining wall work were employed.

In these tests a number was alloted to each brand of waterproofing and the same brand retained the same number throughout.

I Powder 2% by weight

II	Plain unwaterproofed	
III	Powder	2.75% by weight
IV	Powder	2.[illegible]% by weight
V	Paste	1 pt. to 14 of H_2O by volume
VI	Paste	1 pt. to 14 of H_2O by volume
VII	Paste	1 pt. to 12 of H_2O by volume

The following Tests and Methods were employed.

A. Neat Cement Tension Tests. Air Test

Nine standard briquettes of neat cement were made from each of the numbers I - II - III - IV - V - VI - and VII. These were tested in a Fairbanks Shot machine at ages of 1 day, 7 day and 28 day; three of each kind being broken at each age. These specimens were not placed in moist cabinet , but were left in the air of the laboratory : at an average of 65 degrees Fahrenheit , with plenty of outdoor ventilation. The A.S.C.E. single molds were used and the molds were removed at the end of 24 hours.

The cement paste for all briquettes was made of such a consistency that the dropping of a 1 inch ball of the paste to the stone floor from a height of two feet would fletten it to 1/2 inch thickness. The paste was well mixed by a 5 inch trowel on a mm marble slab and the molds were filled by thumb pressure.

B. Neat Cement Test : Moist Cabinet. Temp. of H_2O

The procedure was exactly that of the Air Test ; excepting that instead of seasoning in open air ; upon making , the briquettes were placed in a moist cabinet for 24 hours and then removed from the molds and placed under water until tested.

C. Tension Test. 1 - 3 Sand Briquettes.

Cement and sand in the ratios of 1 part of cement to three of standard 20 - 30 Ottowa Sand were mixed to a uniform consistency for each of the seven numbers. Six standard A.S.C.E. briquetts were made of each variety, and placed in moist cabinet for 24 hours ; the molds were then removed and the specimens were then placed in water until broken. Three specimens of each kind were broken at both ages of 7 days and 28 days. The average room temperature was 65 degrees, the temperature of mixing and storing water was

D. Six Inch Compression Cubes.

From each of the seven test numbers; four standard 6 inch compression cubes were made from 1 - 2 - 4 crushed stone concrete. The sand used was ordinary red torpedo building sand , fairly sharp ; the stone was 1/2 to 3/4 inch crushed limestone. The concrete was proportioned by weight, and shovel mixed by nine turns ; and water added to give a sloppy , liverlike consistency. The molds were gang molds each holding seven cubes ; and were made of 2 inch dressed pine , oiled before using. The forms were removed at the end of 72 hours , and the specimens stored in the laboratory open air (average temperature 65 degrees) until broken. The breaks were made by a 100 ton Riehle Power machine ; 2 of each specimen being broken at the age each of 7 days and 28 days. In testing, perfect bearing was obtained by a universal bearing base-plate ; by padding top and bottom of cube with newspaper, and filling any cavities with plaster of paris.

E. Absorption Tests.

For the absorption tests , 1 - 2 - 4 concrete was mixed in the same manner as for 6 inch compression cubes for each of the seven test numbers. Hemispherical specimens of each was made in a glazdd porcelain evaporating dish , four inches in diameter.

These forms were removed at the end of 72 hours, and the specimens allowed to season in the laboratory air to age of 28 days. At the end of this time each specimen was broken in half, to obtain the natural concrete surface. One half of each specimen was then weighed dry ; then weighed after being immersed in water for a total period of one minute; five minutes ; one hour ; and 24 hours.

F. Permeability Test.

1-5 mortar of each of the test specimens was made from regular torpedo building sand. An ordinary tin cake dish , 9 inches in diameter and 1/2 inch high was then roughly lined with this mortar ; which was made of such a consistency that it would just stand up well when plastered along the sides of the dish. Another tin 8 inches in diameter and 3 inches high was then pressed down into the first and rotated , resulting in the formation of a dish of 1 - 5 mortar ; 8 inches outside diameter with 1/2 inch wall and bottom. The forms were removed after 72 hours , and the specimens allowed to season for 28 days in air. After this time they were filled with water, and the order in which seepage appeared was noted. This test was in the nature of a comparative test only.

G. Permeability and Joint Test.

To test the permeability of 1 - 2 -4 concrete, and also the water resisting value of the joint of one day's work with the next. 1 - 2 - 4 concrete was mixed for each test number in the same manner as for the 6 inch compression cubes. Two inches of each kind of concrete was then tamped into the bottom of a six inch mold (the same mold that was emplyed for the compression cubes). A round tin can , three inches in diameter and four inches high was then placed centrally in each of the two inch foundations. More concrete was then tamped around each can , until the height of concrete was 3 inches. This was then left without slicking the top , in open laboratory air for 24 hours. At the end of 24 hours a joint was made by 1/2 inch of 1 - 2 building sand mortar waterproofed with the same material as the rest of the cube, and then more concrete of the 1 - 2 - 4 proportion made the same as that of the previous day , was added ; completing the height of the cube to 6 inches. At the and of 72 hours the forms and the cans were removed , and the result was a hollow six inch cube with a joint in the middle. At the end of 28 days these were filled with water, and allowed to stand ; and the first appearance and location of seepage noted.

II. Permeability Test.

The principal test of the series consisted of making a hollow cylinder of 1 - 2 - 4 concrete , 16 inches in diameter and 16 inches high from each test number and subjecting it to water pressure. These were made in the following manner. 1 - 2 - 4 concrete was mixed in the same manner and of the same consistency as for 6 inch compression cubes. #22 gauge sheet steel plates, 54 inches long and 16 inches wide were rolled into cylinders 16 inches in diameter and 16 inches high , and secured by three wire hoops around the outside. One of these forms would be placed on a couple of thicknesses of paper on the floor. Concrete was shoveled in and well tamped to an even thickness of four inches on the bottom. A second cylinder , 4 inches high and four inches in diameter was now made by rolling up sheet steel and securing it with one wire hoop. This small cylinder was placed on a piece of thin cardboard, filled with sand and covered with cardboard. It was then placed centrally with the large cylinder, on the 4 inch bed of concrete. More concrete was now shovelled in and tamped around the small cylinder, even to its top. A piece of 4 inch iron pipe threaded at the upper end and 12

inches long was now placed on the small cylinder and the concrete shovelled in around the pipe until the 16 inch cylinderwas filled. The top was floated off and the specimens were allowed to st nd in the open air of the laboratory. At the end of 72 hours the outer form was removed by cutting the wire hoops and removing the sheet steel. By reaching down through the 4 inch pipe, the sand in the small cylinder could be removed, and then the small four inch cylinder was extracted. The result was a 16 inch concrete hollow cylinder with side walls 6 inches thick and bottom 4 inches thick. At the end of 28 days , the ppecimens were filled with water to force out all the air ; and then through a reducer , were connected to a 3/4 inch pipe line. This pipe line could be connected through a valve, either to the city water mains, or to a Marsh pressure pump with a pressure capacity of 10000#/ sq. inch. The specimens were exposed to the city water pressure for four hours, and at the end of that time , if the cylinders had not leaked badly, the pressure was increased by the pump to the point where the cylinders burst. One cylinder was tested at a time, and pressures were read from a Crosby pressure gauge,

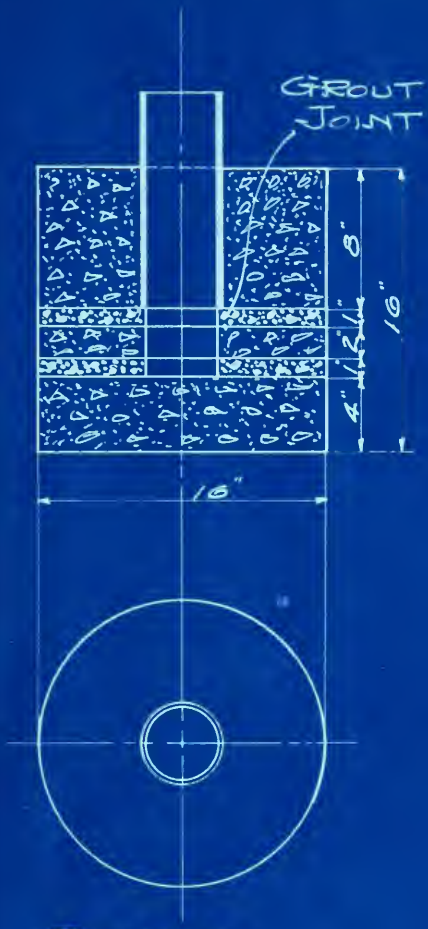
calibrated before and after the test for correctness. When the cylinders were burst open they were carefully examined for signs of seepage.

J. Time of Set.

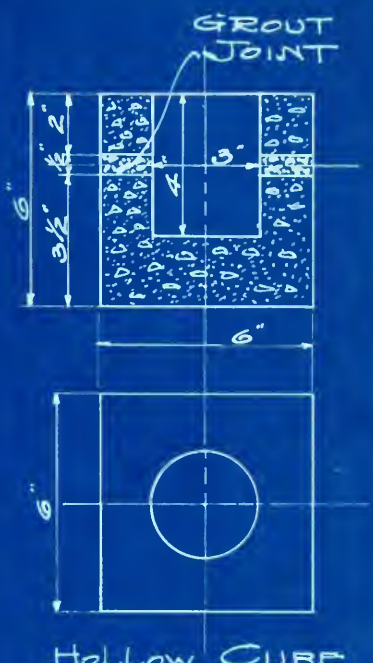
To test the time of set ; the regulation circular pats , 3 inches in diameter and one inch in thickness at the center, tapering to a wafer edge were made up of the neat cement. 26 grams of water being used to mix 100 grams of cement. Thesew were placed in a moist cabinet and the initial and final set were obtained by the Gilmore needle apparatus.

K. Soundness Test.

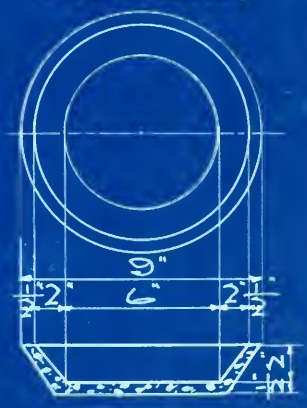
At the age of 28 days , the specimens employed for obtaining the time of set were removed from the moist cabinet and subjected to the boiling test. All stood the test equally well.



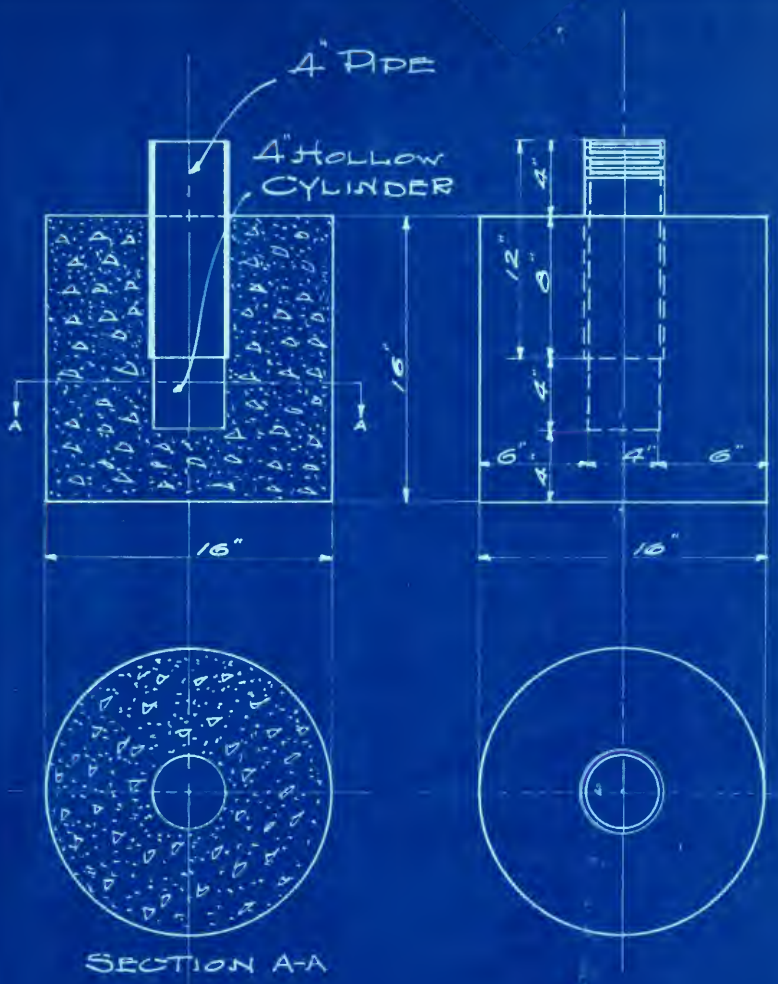
JOINTED CYLINDER



HOLLOW CUBE (JOINTED)



1:5 SAND DISH



VIEWS OF 16" CYLINDERS.

TENSILE TESTS ON NEAT SPECIMENS

MOIST TESTS – LBS. PER SQ. IN.

24 HOUR

	1	2	3	4	5	6	7
	313	306	352	288	313	200	465
	310	212	361	290	387	330	358
	275	227	331	283	380	381	300
Av.	299	248	348	287	360	303	374

7 DAY

	1	2	3	4	5	6	7
	590	695	560	584	825	625	810
	712	650	570	612	800	705	745
	600	645	635	607	795	665	685
Av.	634	663	588	601	806	665	746

28 DAY

	1	2	3	4	5	6	7
	636	760	634	642	798	732	779
	629	825	694	678	698	768	790
	673	673	694	704	—	728	815
Av.	626	752	674	674	748	742	794

AIR TESTS – LBS. PER SQ. IN.

24 HOUR

	1	2	3	4	5	6	7
	288	265	258	320	300	240	243
	252	314	275	330	275	252	286
	263		293	335	267	250	295
Av.	267	290	275	328	286	247	274

7 DAY

	1	2	3	4	5	6	7
	615	235	508	410	405	460	420
	425	380	510	395	382	475	465
	380	275	598	450	400	485	635
Av.	473	296	538	418	425	456	506

28 DAY

	1	2	3	4	5	6	7
	700	275	661	730	436	583	490
	525	285	660	685	502	515	518
	575	220	688	640	408	—	495
Av.	600	243	669	685	449	366	501

Tensile Tests on 1-3 Sand Specimens

Lbs. per Sq. in.

7 Day — Moist.

1	2	3	4	5	6	7
160	215	169	230	200	135	166
188	115	130	190	130	169	195
165	185	178	230	155	163	173
154	171	159	216	161	155	174

28 Day — Moist.

1	2	3	4	5	6	7
272	256	286	268	342	306	311
221	333	248	175	192	387	270
295	338	—	304	—	256	—
262	309	242	249	267	318	290

Compression Tests on 6" Cubes

7 Day

	1	2	3	4	5	6	7
Load	22350	31480	47150	44180	71200	51130	48640
Area	22.50	31.25	36.0	36.0	36.0	36.0	36.0
Lbs. per Sq. in.	994.0	1040	1310	1230	1975	1420	1350

28 Day

	1	2	3	4	5	6	7
Load	49460	49910	69410	70860	92400	83800	86520
"	—	—	68100	65140	117200	78700	93500
Total	—	—	137510	136000	209600	168500	180000
Area	30.0	29.0	72.0	72.0	72.0	69.0	72.0
Lbs. per Sq. in.	1648	1720	1910	1890	2910	2440	2500

ABSORPTION TEST.

ALL WEIGHTS IN GRAMS.

No. 1 - WEIGHT DRY = 831.0

TIME	1 MIN.	5 MIN.	15 MIN.	1 HOUR	24 HRS.
AMT. ABSOR	9.20	12.5	15.0	16.4	18.1
% ABSORB.	2.78	3.77	4.53	4.95	5.47

No. 2 - WEIGHT DRY = 272.2

TIME	1 MIN.	5 MIN.	15 MIN.	1 HOUR	24 HRS.
AMT. ABSOR	10.4	14.3	14.7	14.8	15.3
% ABSORB.	3.82	5.25	5.40	5.44	5.62

No. 3 - WEIGHT DRY = 183.5

TIME	1 MIN	5 MIN.	15 MIN.	1 HOUR	24 HRS
AMT. ABSOR	8.5	10.6	10.7	10.8	11.0
% ABSORB.	4.64	5.78	5.84	5.87	6.001

No. 4 - WEIGHT DRY = 255.7

TIME	1 MIN.	5 MIN.	15 MIN.	1 HOUR	24 HRS.
AMT. ABSOR	6.4	8.5	10.3	10.5	11.8
% ABSORB.	2.50	3.32	4.03	4.11	4.62

No. 5 - WEIGHT DRY = 186.8

TIME	1 MIN.	5 MIN.	15 MIN.	1 HOUR	24 HRS.
AMT. ABSOR	7.4	9.3	9.8	10.0	10.4
% ABSORB	3.96	4.98	5.24	5.35	5.38

No. 6 - WEIGHT DRY = 287.9

TIME	1 MIN	5 MIN.	15 MIN.	1 HOUR	24 HRS.
AMT. ABSOR	6.8	9.6	11.5	11.9	13.9
% ABSORB.	2.36	3.36	4.00	4.13	4.83

No. 7 - WEIGHT DRY = 221.2

TIME	1 MIN.	5 MIN.	15 MIN	1 HOUR	24 HRS
AMT. ABSOR	5.4	6.5	7.5	8.6	10.0
% ABSORB	2.44	2.94	3.39	3.89	4.52

PERMEABILITY TEST
ON 16" CYLINDERS

NUMBER 1

WITHSTOOD 14 LBS. PRESSURE FOR 14 HOURS BURST AT 650 LBS.. WATER HAD PENE-TRATED THE CONCRETE TO A DEPTH OF $\frac{1}{4}$ INCH.

NUMBER 2

WATER SEEPED THRU FREELY IN VERY SHORT TIME WITH 14 LBS PRESSURE

NUMBER 3

SHOWED SAME ACTION AS No 2. SEEP-AGE UNDER 14 LBS. IN SHORT TIME.

NUMBER 4

SHOWED A VERY SLIGHT LEAKAGE AT END OF 4 HRS. OF CITY PRESSURE (14 LBS). BURST AT 600 LBS., SHOWING CONCRETE SOAKED THRUOUT.

NUMBER 5

WATER LEAKED FREELY AT ONCE WITH CITY PRESSURE.

NUMBER 6

SHOWED VERY SLIGHT LEAKAGE AT END OF 4 HRS. UNDER 14 LBS., BURSTING AT 580 LBS.. SHOWED AVERAGE WATER PENETRATION OF 2 IN., WITH ONLY ONE LEAK CLEAR THRU.

NUMBER 7

SHOWED LEAKAGE ALONG A SHORT SINGLE LINE AFTER 4 HRS OF 14 LBS PRESSURE. BURST UNDER 500 LBS., SHOWING AVERAGE PENETRATION OF $1\frac{1}{2}$ IN.